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MASS RATIOS

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1·0. Introduction

One of the most fundamental relations in rocketry is the equation:—

$$v_c = v_e \log_e \frac{M_o}{M} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where:—

v_c = the characteristic velocity of the rocket.
v_e = the average effective exhaust velocity.
M_o = initial rocket mass.
M = final rocket mass.

The derivation of this well-known equation is given in all the classic works on the subject and follows simply from consideration of the conservation of momentum between the rocket and its exhaust. Physically, the velocity v_c so obtained is the one which the accelerating rocket would finally achieve in field-free evacuated space, if all its propellants were continuously exhausted from ignition to all-burnt. Equally, however, v_c is the sum of all the separate velocity increments which would be imparted to the rocket if its propellants were used in a series of bursts on different occasions—*i.e.* for given values of v_e and $\frac{M_o}{M}$, the rocket could accelerate to a velocity v_c once, or to v_1, v_2 and v_3 on three separate occasions, where $v_1 + v_2 + v_3 = v_c$.

This latter consideration suggests a convenient method of dealing with rocket performance calculations, which has found much favour with workers in the field of astronautics (*e.g.* see reference 1). On this basis, the characteristic velocity v_c becomes the sum of all the velocity requirements on various separate occasions during the mission of the rocket, including the velocity losses which have to be made good on those various occasions due to the actual presence of retarding gravitational fields, air-drag, etc.

The quantity $\frac{M_o}{M}$ in equation 1 is termed the *mass ratio* (R), and this again is a very familiar and important expression. If the rocket is a simple single step design, its use is clear and unambiguous, but where multi-step rockets are concerned, there is (judging from the literature) considerable scope for confusion of one sort or another. Indeed, for multi-step rockets there are a number of different "mass ratios" all having considerable interest and physical significance —it is the purpose of this paper to attempt a clear definition of them.

2·0. Ratios for Step Rockets

Consider the step rocket shown diagrammatically in Fig. 1. It has n steps numbered consecutively from 1 (the first, bottom or take-off step) to n (the last, top or final step). Then:—

M_1 = Mass of first step, full of propellants.
m_1 = Mass of first step, empty of propellants.

and so on, through M and m, until M_n and m_n for the last step.

The mass m_n includes the mass of that final payload ($= m_l$, say) which is carried throughout the mission. Thus, m_l would comprise the crew and/or instruments, while m_n would include m_l together with the structure and tankage weight of the nth step.

The various mass ratios relevant to any detailed discussion of step rocket performance are then as outlined below.

2·1. True Mass Ratio

Clearly, in any assessment of the magnitude, expense or difficulty of a project to build a rocket for a particular mission, the primary interest is in what will be called here the *true mass ratio*. This is the ratio of total mass at take-off to final mass landed back on Earth (or at destination, if return is not contemplated), and this quantity (R_o) is given by:—

$$R_o = \frac{\Sigma_1^n M}{m_n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

However, R_o is *not* the "mass ratio" to insert in equation (1), in order to obtain the characteristic velocity of the whole step rocket; if it were, there would be no virtue in the step principle. It remains to derive an effective mass ratio for the whole assembly.

2·2. Individual Step Mass Ratios

If the separate steps were used as single rockets on their own, each would obviously have an *individual mass ratio* (r_i), determining its performance according to equation (1).

For the first step:—

$$(r_i)_1 = \frac{M_1}{m_1},$$

for the last:—

$$(r_i)_n = \frac{M_n}{m_n}$$

and in general:—

$$r_i = \frac{M}{m} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

The various values of r_i for the individual steps are not, of course, necessarily equal.

2·3. Effective Step Mass Ratios

When all the steps are used in series, each as part of the whole assembly, then each makes some contribution to the overall effective mass ratio. The *effective mass ratio of each step* under these conditions, however, is not equal to r_i as given by the preceding equation (3), except for the last step.

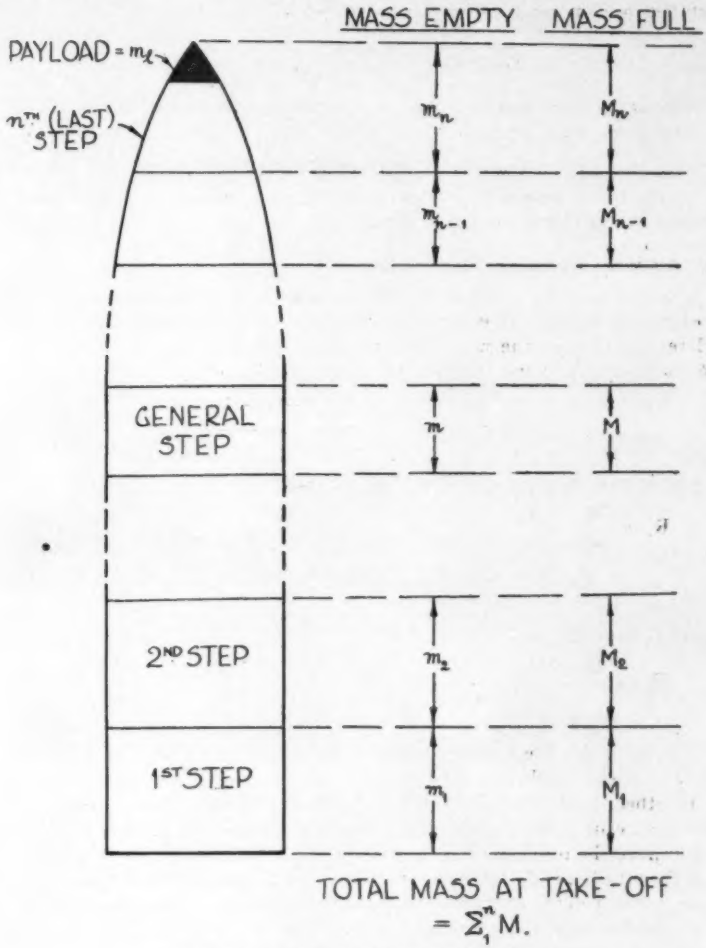

FIG. 1. Diagram of Step Rocket.

If the effective step mass ratio is called r_e, then for the first step:—

$$(r_e)_1 = \frac{M_1 + M_2 + \ldots + M_n}{m_1 + M_2 + \ldots + M_n}$$

while for the last step:—

$$(r_e)_n = \frac{M_n}{m_n} = (r_i)_n$$

as stated, and in general, for the xth step:—

$$(r_e)_x = \frac{\Sigma_x^n M}{m_x + \Sigma_{x+1}^n M} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Here again, the value of r_e may not be the same for all steps. Elementary considerations show that:—

$$r_e \leqslant r_i \text{ (compare equations (3) and (4)).}$$

but, with this fundamental reservation, r_e can be assigned any value the designer chooses for a particular step.

2·4. Overall Effective Mass Ratio

It is now possible to derive the *effective mass ratio of the whole assembly* (R_e). As each step finishes firing, it will have communicated its own final velocity to all later steps, hence the sum of the velocities so contributed by all the *effective step mass ratios* is equal to the total v_e of equation (1). It follows that:—

$$R_e = (r_e)_1 \times (r_e)_2 \times ---- \times (r_e)_x \times ---- \times (r_e)_n \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Expanding this expression, we see that:—

$$R_e = \frac{M_n}{m_n} \times \frac{M_{n-1} + M_n}{m_{n-1} + M_n} \times \frac{M_{n-2} + M_{n-1} + M_n}{m_{n-2} + M_{n-1} + M_n} \cdot$$
$$---- \times \frac{M_1 + M_2 + ---- + M_n}{m_1 + M_2 + ---- + M_n}$$

whereas (from (2)) we have:—

$$R_o = \frac{M_1 + M_2 + ---- + M_n}{m_n}$$

$\therefore R_e \ll R_o$.

For $R_e = R_o$, the empty masses of all steps except the last (*i.e.*, m_{n-1}, $m_{n-2} --- m_1$) would have to be zero, an obviously ridiculous condition.

In other words, the multi-step rocket buys its high *effective* mass ratio at the expense of a truly staggering *true* ratio, of take-off to final mass. This should never be overlooked in studying the results of calculations which show only the gratifying characteristic velocities made possible by the high effective ratios. For a given exhaust velocity, the multi-step rocket will often be the only possible way of obtaining a certain high performance, but it may still remain a very extravagant means of doing so.

3·0. Alternative Parameters

In the published literature, various alternative terms have sometimes been used, and these will now be correlated with those employed here.

In reference 2 and elsewhere, for example, the parameter α is introduced, where:—

$$\alpha = \frac{\text{Propellant mass}}{\text{Total mass}}$$

$$= \frac{M - m}{M}$$

$$= 1 - \frac{1}{r_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

Obviously, this is merely an arithmetical alternative, and for each of the senses in which particular sorts of "mass-ratio" have been used here, it would equally be possible to set up the appropriate equations for a parameter of the "α" variety.

References 3 and 4 have employed the terms:—

Structural factor (ϵ)
Payload ratio (λ)

and *Propellant loading ratio*, or
Propellant mass ratio (ζ).

It is suggested that the use of the first two of these parameters, in particular, has some attractions, in so far as it avoids the confusion inherent in talking of various different sorts of "mass ratio." Using the nomenclature of Fig. 1 and equations (2) to (5), these quantities are defined as follows:—

$$\epsilon = \frac{m}{M} = \frac{1}{r_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots (7) \text{ cf. } (3)$$

with the reservation that, as employed in references 3 and 4, for the last step we have:—

$$\epsilon_n = \frac{m_n - m_l}{M_n - m_l} \left(\text{not } \frac{m_n}{M_n} \right)$$

$$\neq \frac{1}{(r_i)_n}, \text{ unless } m_l \text{ is negligible.}$$

This particular usage is quite logical, on the following grounds: there is no reason why the last step should not have a "structural efficiency" (or factor) as good as the lower steps. On the other hand, since it has to contain all the payload, its "individual mass ratio" $= (r_i)_n$ can be expected to be poorer than those of the lower steps; this is readily shown up by the convention adopted by the GALCIT authors of the references in question. (If the lower steps carried any payload—*e.g.* a crew to carry out a landing manœuvre—then a similar convention would be indicated in their case.)

$$\lambda_n \text{ (for last step)} = \frac{m_l}{M_n}$$

or (in general)

$$\lambda = \frac{\Sigma_{x+1}^{n} M}{\Sigma_x^n M} \quad \ldots\ldots\ldots\ldots\ldots (8)$$

Finally,

$$\zeta = \frac{\Sigma_1^n M - \Sigma_1^n m}{\Sigma_1^n M} \quad \ldots\ldots\ldots\ldots (9)$$

Thus ζ represents the ratio of total propellant mass to gross take-off mass, and is a parameter of the "α" variety for the whole rocket assembly.

In the references quoted (3 and 4), it is suggested that the individual steps of a multi-step rocket (unless their mass is very small) could all be built with an equally good value of ϵ. (The one chosen would of course be the minimum practical value, *i.e.* the maximum possible "individual mass ratio," r_i). Also, a proof is outlined showing that the optimum arrangement is that in which λ (or r_s) is constant for all steps. *For these conditions* of constant ϵ (on the authors' convention) and λ, it follows that

$$\zeta = (1 - \lambda)(1 - \epsilon) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

and

$$R_e = [\epsilon(1 - \lambda) + \lambda]^{-n} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

The authors also introduce the term "overall mass ratio" (G), in the sense of an overall payload ratio, such that:—

$$G = \frac{\Sigma_1^n M}{m_l} \text{ in our symbols,} \quad \ldots\ldots\ldots\ldots\ldots \quad (12)$$

and show that

$$G = \lambda^{-n} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

4·0. Numerical Values

The payload ratio (λ) can obviously be as small as the designer is prepared to tolerate, and the smaller it is, the higher will be the characteristic velocity which the rocket will attain. Assuming a rocket—either single step or the final step of a multi-step assembly—with a certain propellant mass and necessary structural mass, then if the payload is reduced, so is the effective mass ratio improved. (In general, of course, a further small reduction in required structural mass would also be possible with reduced payload.) Such a procedure amounts to a decrease in λ. However, practical economics will obviously fix a lower limit to the acceptable λ; nobody would be prepared to accept an individual step of 1,000 tonnes initial mass to carry 1 kg. of payload ($\lambda = 10^{-6}$), especially since the optimum arrangement is equal λ for all steps. Values of λ for various rockets of outstanding interest are shown in Table I.

Of more fundamental interest, because it is a parameter decided by the extent and quality of our structural engineering knowledge, is the attainable value of ϵ. Any discussion of possible rocket performance must, in fact, start from a consideration of what is reasonably practical in this direction. It is not generally realised what a large advance is required, in design ingenuity and/or in the mechanical properties of available materials, in order to achieve what may appear to be only a small improvement in ϵ (say, from 0·25 to 0·20). Some data on structural factors is given in Table II.

Apart from considerations of what has already been achieved by the application of careful design technique to actual rockets, some light on possible ultimate ϵ values may be obtained from a study of comparable factors for modern long-range aircraft (*i.e.* ratio of empty to loaded weight, excluding items such as wing weight and heavy power plant weight not relevant to the rocket case). All such reflections suggest that ϵ values much below 0·20—for example, the 0·10 which has sometimes been quoted—are, to say the least, highly optimistic.

The structural factors of rockets using low density propellants are, of course, likely to be much higher than for dense propellants, because of the increased tankage volume required. This is unfortunate, because many of the chemical propellant combinations giving highest exhaust velocity are of low specific gravity; it is for this reason that such combinations as hydrazine and fluorine may be preferred to the more commonly quoted "ideal" of hydrogen and oxygen. Again, the weight of radiation shielding required for a hypothetical nuclear-powered rocket will have an adverse effect on its possible structural factor, while the propellant density argument may, even for this case, dictate a choice of some heavier working fluid than the obvious "ideal" of hydrogen. High accelerations will tend to imply low structural factors, due to the stresses set up, but on the other hand there will be a favourable effect with increasing rocket size, at least up to a certain optimum mass.

TABLE I

Rocket	λ
V.2 (A.4)	0·08
WAC Corporal	0·04
Viking (ex-Neptune): Max. payload	0·17
" " Min. "	0·01
Rheinbote: Last (4th) step	0·20
" 3rd "	0·34
" 2nd "	0·58
" 1st "	0·59

TABLE II

Rocket	Propellants	ϵ
V.2 (A.4)	Oxygen/ethanol	0·24
WAC Corporal	Acid/aniline	0·44
(N.B. Small rocket.)		
Viking (ex-Neptune)	Oxygen/ethanol	0·21
Rheinbote: Last (4th) step	Solid	0·62
" 3rd "	"	0·64
" 2nd "	"	0·67
" 1st "	"	0·65
Probable best attainable (see Refs. 3 and 4).	Liquid of high density, *e.g.* oxygen/ethanol, or acid/aniline.	0·20
Probable best attainable (see Refs. 3 and 4).	Liquid of low density, *e.g.* oxygen/hydrogen.	0·33

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ASTRONOMY AND ASTRONAUTICS

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A lecture delivered to the British Interplanetary Society in London on April 2, 1949.

My task to-night is to give to you an insight into the impact which present and future developments in the field of rocket propulsion may make upon the science of astronomy and astrophysics. It is a task for the discharge of which I feel myself woefully inadequate. Those of you who have come in the mood for philosophical discussion will be disappointed. Equally disappointed will be those who expect a preview of the universe that will be presented to observation a century hence; I do not intend to embark upon so rash a venture. Instead, I shall treat the subject in a prosaic manner. The rocket will be considered as a potential tool of astronomical research, and I shall try and give reasons for believing that it may well be a very important tool. In following with me this perhaps rather uninspired course, you must not hope for any startling revelations; but I can, I think, say that I may have a few surprises up my sleeve for those who think that the only use of rockets in astronomy will be to find the physical states of the planets!

The importance of rocket research to astronomy is that it will enable observations to be made from outside the earth's atmosphere. This atmosphere, important as it may be for the physical well-being of the astronomer, disturbs the light-signals from the objects under his observation in important ways. Firstly, it produces unsteadiness of image; the atmosphere is in a more or less highly turbulent state and variations of temperature and pressure over small regions continually occur. The resulting change in refractive index alters the direction of the light passing through. The continual local changes of atmospheric conditions thus cause irregular changes in the position of the image of a fixed object in the telescope. The frequency of these changes is great, but the eye is able to follow them to some extent. It is difficult to give a quantitative estimate of the magnitude of the effect, which will vary according to local ephemeral meteorological conditions. The atmosphere also scatters starlight much as the light of a street lamp is scattered by the particles of a fog. This has the effect of reddening the star-light, reducing its intensity, and contributing to a general background illumination. While correction for these effects can be made by observations at different angular distances from the zenith, such correction can never be entirely satisfactory. The night sky is never completely black. This background illumination arises from three different sources; about 25 per cent. is the scattered starlight already mentioned; 15 per cent. is due to emission by atmospheric atoms and molecules excited by some external radiation, and the remaining 60 per cent. is caused by the zodiacal light, the sunlight reflected from small particles or electrons outside the Earth, pursuing orbits about the Sun.

The human eye is less sensitive than the photographic plate largely because the latter can build up an image by long exposure. Astronomical observations

are mostly made photographically, but just because of this property of accumulative sensitivity, the photographic plate will record a star as a disc of confusion due to the total effect of the atmospheric unsteadiness during the exposure time. This exposure time is itself limited by the fogging produced by the compound night sky light. Even outside the Earth's atmosphere the sky would not be completely black. From the Moon, while the effects of atmospheric unsteadiness and the scattered starlight and night sky emission would be no longer present, the 60 per cent. of the night sky light that is due to the zodiacal light would still be troublesome, and would be so unless we could observe from outside the orbit of Jupiter.

A third effect of the Earth's atmosphere becomes apparent when we observe the spectra of planets and stars; this is selective absorption. Due to the properties of the molecules of the atmosphere only a small proportion of the whole electromagnetic spectrum impinging upon the outer atmosphere eventually reaches our recording instruments. The extent of this absorption is indicated in Fig. 1. The human eye has so evolved as to be sensitive to a very small range of wave-lengths within one of the regions of atmospheric transparency. Observations have in the past been more or less confined to the visual region, and the regions of the ultra-violet and infra-red spectrum lying near it in the "optical window." To the violet side of this window, the absorption due to oxygen and ozone produces a very sharp cut-off, and one of the immediate uses of the rocket in astronomical research is to increase our knowledge of the solar spectrum by pushing into the ultra-violet regions of the spectrum obscured by the total atmosphere. On the infra-red side of the optical window, the cut-off is less pronounced, absorption being produced by molecular absorption bands. In the region of the centimetric waves, a second window in the atmospheric absorption appears, the "radio" window. Recently radiations from celestial objects within this range have been studied,[1] and the rather unexpected results serve to emphasise what a real limitation to our knowledge of the universe is the absorption of the Earth's atmosphere. As well as these extended regions of absorption, even in the visual and optical window certain discrete wave-lengths are absorbed, to cause "telluric lines" in stellar spectra.

So much, then, for the adverse effects of the Earth's atmosphere. What can be done about it? The recent developments of rocket propulsion show that man has already in his possession a means of partial escape from this observational imprisonment. To use an inapt simile, let us start with our feet on the ground and examine something of what has been or could be achieved with present equipment.

In as much as the study of planetary atmospheres finds a place in astrophysical research, so with some justification could meteorological investigations be treated here, but space forbids more than the mention of a more specifically astronomical discovery made recently, the identification of a telluric band due to nitric oxide in the ultra-violet spectrum of the Sun. One of the first experiments to be performed with rockets was, of course, the photography of the solar spectrum in the upper atmosphere, where absorption should be small or possibly negligible if sufficient altitudes could be reached. Durand, Oberly and Tousey of the United States Naval Research Laboratory have recently published the

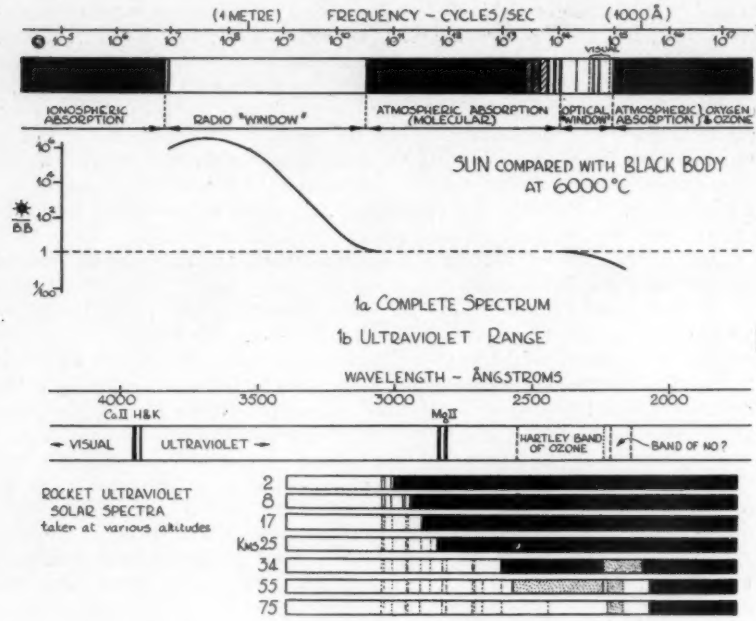

FIG. 1. The Electromagnetic Spectrum.

Fig. 1a shows the complete spectrum in the frequency range of 10^{17} to 10^{8} cycles per second. The upper diagram shows the regions of the spectrum absorbed by the total atmosphere of the Earth, and the radio and optical "windows." Telluric lines, and band absorption on the infra-red side of the optical window have been indicated. The lower diagram shows the intensity of solar radiation at the different wave-lengths accessible to observation, with the theoretical intensity for a black body at 6,000° C. taken as unity at all wave-lengths.

Fig. 1b shows a small portion of the spectrum about the limit of the visual violet (marked approximately by the H & K CaII lines). The wave-lengths recorded by rocket spectra taken at different heights are shown diagrammatically, and the positions of those features of the spectrum in this range mentioned in the text have been indicated.

analysis of the first rocket ultra-violet spectra of the Sun taken between October, 1946 and October, 1947.[2] (Further interesting details of the equipment and the spectra are given in[14]). A spectrograph, specially designed to allow for rolling of the rocket in flight, recorded wave-lengths in the range below 3500Å on 35mm. ultra-violet-sensitised film which was automatically wound into an armoured-steel casette. This casette, after maximum altitude had been reached, was fired from the main body of the rocket by air pressure and recovered. Successful spectra were taken between ground level and 75 km. (effectively above the ozone layer of the atmosphere). The previously

unobserved portion of the Sun's spectrum brought to light at different altitudes is shown also in Fig. 1. Special note should be taken of the 34-km. spectrum, which shows radiation down to 2100Å, but with an absorption band about 2550Å. This is the Hartley band due to atmospheric ozone. The spectrum at 55 km. was high enough above the ozone layer to photograph throughout this range, although the original negative shows a slight absorption due to residual ozone above the rocket. As well as confirming the presence of this known band of oxygen, the spectra revealed absorption between 2200 and 2280Å. which could not be interpreted as due to lines in the solar spectrum. The only possible interpretation would appear to be that of band absorption by some atmospheric molecule, and while the identification is not certain, it is possible that this band is due to nitric oxide (NO). A layer of only 0·5 mm. thickness at N.T.P. would produce measurable absorption, and consequently the spectrum taken at 55 km. could have detected in the atmosphere above it a concentration of only 0·01 per cent. of NO.

As well as telluric lines and bands due to the Earth's atmosphere, some 200 previously unknown lines in the solar spectrum were provisionally identified. One pair of lines in particular is of interest, the doublet of magnesium MgII at 2863 and 2796Å., for this was seen with central *emission*. Only one other atom in the Sun's outer regions produces lines with central emission in the spectrum of the total Sun, and this is the analogous CaII H & K doublet just in the visible violet region of the spectrum, but the MgII emission is much more intense. This doublet may well be enhanced in solar flares, and is of a suitable wave-length to explain many of the known terrestrial effects of solar flares.

The general level of intensity of the solar spectrum in these previously uncharted wave-lengths was also measured, and compared with the theoretical "black-body" curve for a temperature of 6,000° C. The results and importance of this work are discussed later.

These preliminary spectra were taken with original German V.2 at heights of less than 75 km. As members will know, rockets of American design have already proved themselves above 200 km. More spectra must at this moment be in the process of analysis—it will be interesting to see what new facts they reveal. But we must not underestimate the difficulty of sending a rocket effectively outside the Earth's atmosphere. It is difficult to make a sound assessment of the absorption of the atmosphere at different heights, for the only data available is laboratory data taken with air at different *pressures*. Zwicky has estimated that a height of 1,000 km. must be reached for atmospheric absorption to be negligible.

The reference to solar flares brings to mind another piece of work within the scope of present achievement, which, although perhaps more strictly geophysical, would be of interest to astronomers. It is well known that the appearance of a flare in hydrogen (Hα) light on the Sun's disc produces characteristic sudden change in the Earth's magnetic field. Concurrently with the flare, a small disturbance of characteristic shape appears on continuous traces of the Earth's field, and is followed about one day later by a much more violent "magnetic storm." The flare is believed to emit both electromagnetic radiation

which travels with the speed of light and causes the crochet (it may be the MgII radiation previously mentioned), and as well, a beam of corpuscles travelling much more slowly which meet the Earth's atmosphere about 24 hours later to cause the magnetic storm. The detailed explanation of these effects has led to the belief that small transient changes of the general magnetic field of the earth are caused by circulating electric currents in the upper atmosphere. (For a popular account, see[3].) These currents are, however, largely speculative, and there would seem no reason why their actuality should not be confirmed or denied by electrical "sampling" by rockets. Should their existence be confirmed, information on their height and current density could be obtained; such information cannot be obtained uniquely from the present theory. (As well as the terrestrial magnetic effects of solar flares, a more or less regular diurnal occurrence over limited periods of less intense storms is associated with at present unidentified *M-regions* of the sun's surface.)*

The study of meteors has been, until the last few years, something of a backwater of the river of astronomical progress, the prerogative of a few enthusiatic amateurs. This is not because of any lack of importance to the investigation of meteors; indeed, it is of the utmost importance in the still baffling problem of the origin of the solar system. No, it has remained a backwater (although a by no means stagnant one!) because, the telescope, spectroscope and photographic plate being at a disadvantage with a phenomenon so transient as a meteor, study has been almost entirely in the hands of visual observers, and visual observations, useful as they are for geometrical observations of meteor paths, can give little knowledge of the physics of the meteor and its interaction with the atmosphere. Recently the backwater has become a sizeable stream! The discovery that radar echoes could be obtained from meteors stimulated interest. In the early days of this work one used to speak of "radar *detection* of meteors"; now one must speak of radar *observations* of meteors and their effects, for in a very short time, workers, primarily those under Blackett and Lovell at the University of Manchester, have brought the study of meteors by radar to a fully-fledged astronomical and meteorological technique. The photographic study of meteors is also taking a new lease of life with the new Schmidt cameras under Whipple at Harvard. These new observations have, in their turn, brought new and interesting theories of the meteor phenomena (*e.g.*[4]) but throughout the limitation is always that we only *observe* the meteor and its effects; how different the situation would be if we could *experiment* with meteors. The effects of different masses, velocities, composition, etc., which can now only be tentatively surmised, could be determined directly by experiment. The solution, one perhaps already in our grasp, is to project artificial meteors into the atmosphere from rockets, and photograph, observe and follow by radar techniques the resulting effects. Zwicky in America already has such a project in hand. Early unsuccessful attempts were made in 1946–7,[16] but development has for some reason appeared slow, and while the technique has undoubted promise it has so far failed to produce significant results.

* Some correlation between magnetic storms and characteristic regions of the Sun's corona suggest that the M-regions may be located there.

So much for the briefest of glances at some of the potentialities and achievements of present rocket research. We must now make a jump into the future, to the time when we are able to make observations outside the Earth's atmosphere on something like the scale of our present astronomical observations, to the time, in fact, when it has been found possible to set up a lunar observatory.* But before such an observatory has been established, the moon itself will have come under examination, and it is worth pausing to have a look at some of the problems whose solution may then be found. The density of the Moon, which is only about one-half that of the Earth, is something of a mystery. If the Moon, as is commonly thought, was originally part of the Earth, then its composition must be similar, and the conclusion is that the Moon has a hollow structure. On the other hand, the Moon is a rather exceptional satellite, and the possibility of its being a separate planet that was captured by the earth is not to be ignored. The origin of the characteristic features of the lunar surface, craters, mountain ranges and "seas," is far from being understood. (The rival theories of volcanic activity and meteoric impact have been discussed by the Society before, and need no amplification here.) Of the many detailed problems of selenology, one that is of particular interest is the nature of the lunar rays. These rays are bright streaks, some five or ten miles wide, which radiate from a few craters, and travel in straight lines for great distances without regard for the topography of the ground they cover; the rays round Tycho are the most prominent. (For more details of these and other lunar formations, see[15].) Pease has seen the rays as "the illuminated sides of low mounds which always cast their shadows in the same direction that the neighbouring craters do," but other observers do not appear to agree with this interpretation, and it is generally stated that the rays do not cast a shadow at any angle of illumination. A more likely explanation is that they are some finely-divided form of lunar material flung out from the crater. Metallic pellets have been found associated with a terrestrial meteor crater, and further, the opportunities afforded by two world wars in the examination of artificial explosions show that matter ejected at such times has a definite tendency to fall in radial streaks very similar in aerial appearance to the lunar rays. On these grounds the rays have been cited by the protagonists of the meteoric theory in support of their contentions.[18] It would appear difficult on any theory supposing a common time of origin of rays and crater to account for the fact that the rays pass undeviated over other craters overlapping the crater associated with the rays, and therefore of later formation; for this reason, the rays have also been cited as giving confirmation to the volcanic theory.[6] The matter is clearly open, and it is a matter of some importance to selenology.

The magnetic field of the moon, if one exists, will be early measured. Not only is it of intrinsic interest, but it is of paramount importance for the discussion of "fundamental" theories of the magnetism of the Earth and stars, of which that of Blackett has been given much prominence recently. I have

* This statement does not imply a lack of interest in the "orbital base" projects, but only that, from the point of view of this discussion, such a base affords only those opportunities which are afforded to a much greater degree by a lunar observatory, and consideration would involve repetition.

given an account of their theory, and the evidence for it, in a previous *Journal*.[8] Since that writing, further evidence on stellar fields, including the discovery of large *pulsating* magnetic fields on certain stars have tended to weaken the case for the new theory, but the matter is still under discussion, and further evidence is necessary. The importance of the moon in the train of possible evidence has been emphasised in the article cited.

And so to the lunar observatory! I shall leave to others the task of describing and overcoming the various engineering difficulties in the way of its realisation—these do not come within the province of my subject. Nor shall I attempt to predict a date for its realisation, for this I am not competent to do. Let it suffice that reason enough exists for the belief that its final realisation is likely, in the not too distant future. But before attempting to show its advantages, a few words might not be amiss on some of the difficulties that will be encountered (on the astronomical, not the engineering side) in its construction. Richardson of Mount Wilson Observatory has dealt with such a subject,[11] and the following points are taken largely from his leaflet. Communication with the Earth by radio will have to use frequencies to which the Earth's ionosphere is transparent. At sunspot maximum the minimum frequency is about 12,000 kc./sec., and at minimum 6,500 kc./sec. The source of power, which may well be solar radiations, will have not only to drive the telescope and heat the observatory, but also heat the bearings of the various instruments, as no lubricant could function at $-100°$ C. With the development of quartz oscillation clocks, and more recently the "molecular clock," accurate time-keeping will not be a difficulty. The mirror of the main telescope will be vulnerable to meteoric bombardment. The difficulty of estimating the number of meteors striking a given area in a given time has been emphasised in a previous paper on meteors written in 1946[7]; the problem is as difficult at the present time. However, pessimistic assumptions from known data seem to give a 300-in. disc a life-time of some 2,000 years, so perhaps the situation is not too serious.

A problem of more routine interest is the driving of the telescope. To follow a star a terrestrial equatorial telescope is driven about an axis parallel to the Earth's axis, pointing to the pole of the heavens. This pole is not fixed, but rotates about a fixed point in the sky, the pole of the ecliptic, in a circle of radius $23°{\cdot}5$ with a period of revolution of 26,000 years. The effect of this "precession" is sufficiently small to be allowed for by second-order corrections to tabulated star positions, etc. The Moon's pole, on the other hand, is only $1°{\cdot}5$ away from the pole of the ecliptic, and it travels round it in only 18·5 years (see Fig. 2). The effect is now far from second-order; Richardson quotes for a 100-in. telescope with exposure of 2 days, a length of trail of star image due to this precession of 1 in. This difficulty is not, of course, insurmountable. At the worst, a telescope could probably be mounted on a double equatorial with two clock drives, the polar axis itself rotating about a fixed "ecliptic" axis with the required period of 18·5 years. Alternatively, a small "jockey" instrument could be mounted in this way, and the large instrument controlled electronically from this. Indeed, it would probably be possible to design a complete electronic drive for an altazimuth mounting and dispense with the

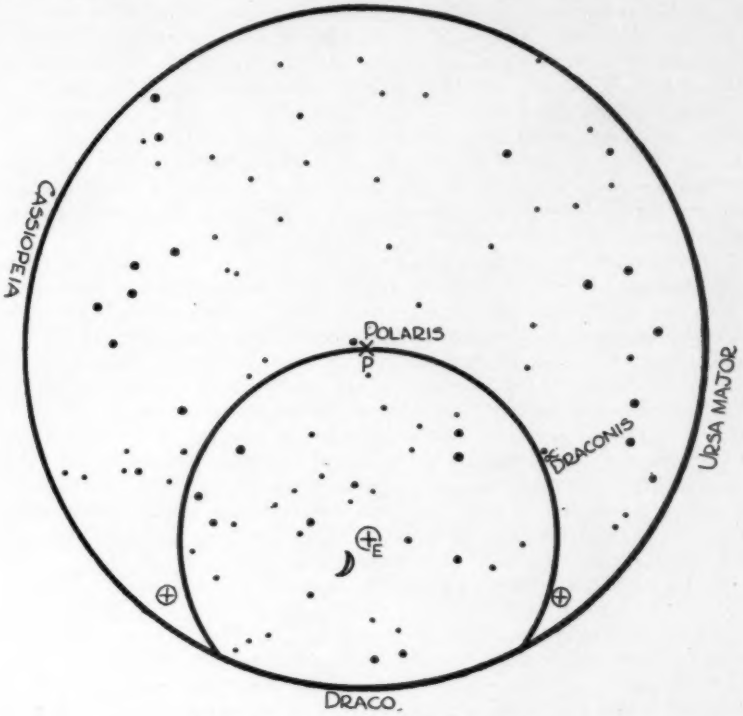

FIG. 2. Lunar and Terrestrial Precession.

The diagram shows the paths of the terrestrial and lunar poles among the brighter northern stars.
The Earth's pole travels around the large circle marked ⊕⊕ centred about the pole of the ecliptic, E, with a period of complete revolution of 26,000 years. The present position of the Earth's pole is P, near the star Polaris, α Ursa Minoris. The other bright star near this circle is α Draconis, which was the terrestrial pole star some 4,600 years ago. The path of the lunar pole is a much smaller circle, also centred about E, and marked with a crescent). The period of revolution of the Moon's pole is only 18·5 years.

"jockey." Or, for much work, the plateholder itself might be driven in a compensating manner.

I now come to the most important, but at the same time the most exacting part of my task this evening, to give some impression of the way in which a lunar observatory will influence the progress of astronomy. And yet I cannot say to what tasks such an observatory will be directed. The picture of the universe that we have at present has largely grown with the rise of modern astrophysics; it has behind it some three-quarters of a century of history. At a conservative estimate, something of the same order of time will have

elapsed before my speculations to-night could become reality. Who can say what our picture of the universe will be then, or what problems will exercise the minds of astronomers of the future? I certainly cannot. But whatever the problems, the lunar observatory cannot help but profoundly influence their solution. I think, therefore, that my purpose will be best served to-night if I take some present problems of astrophysics, and by showing the way in which the vagaries of the Earth's atmosphere hinder the pursuance of these problems, let them serve as *illustrations only* of the importance of astronautical research as a potential influence on astronomy. The particular problems may go, but the properties of the atmosphere will always be with us!

It is not difficult to find such examples. Almost any branch of astrophysical research has errors which, in the final analysis can be shown to be limited by atmospheric properties. An extreme example is provided by the telluric absorption lines, which all but preclude completely the detection of similar absorption lines in planetary spectra. For instance, the water-vapour content of the Martian atmosphere is very uncertain for this reason. It has been demonstrated (see *e.g.*[13]) that this atmosphere does contain a little water vapour by taking spectra of Mars and the Moon at similar altitudes on a very dry night, and comparing the intensities of the water-vapour bands. The vast majority of the absorption is due to molecules in the Earth's atmosphere; small differences of intensity have been interpreted as due to water-vapour molecules in the atmosphere of Mars. It is not surprising that astrophysicists will not be pressed to definite statements on the matter!

Still in the solar system, we turn to observations of the Sun. These are limited, of course, by the absorption which only allows a few windows in the electromagnetic spectrum. We have seen how far rockets have gone to the relieving of this difficulty. When the complete range of spectrum is available for examination, we will be able to see exactly how the quality of the Sun's radiation differs from that of a black-body at the temperature of the solar surface ($\sim$ 6,000° C.). It is already known that at radio wave-lengths that can be observed the radiation is much higher than this, while the rocket experiment cited[2] have shown that it drops below the black-body temperature of 6,000° C. in the ultra-violet (see Fig. 1). The reason for this would seem to be that the different wave-lengths originate at different levels of the solar atmosphere, and so information over the whole of the spectrum, and not just isolated "windows," will enable us to build up a complete mechanical picture of the outer layers of the Sun.[1] This we can only imperfectly do at present. In solar research the corona, too, will at last get its fair share of observation. This diffuse outer extension of the Sun's atmosphere is so very faint that, apart from the transitory glances during total eclipses of the Sun, it has only been observed satisfactorily at high-altitude observatories using very delicate optical equipment from which scattered light has been eliminated. The scattering in the atmosphere still renders observation difficult. When this latter limitation no longer applies, our information on the relation between the rather puzzling corona (at a temperature of some million degrees centigrade![8]) and other solar phenomena such as flares and sunspots, will be greatly enhanced.

The Sun is but an average star. In the space between the stars lie tenuous

clouds of interstellar matter. We recognise these clouds by the characteristic absorption lines which they produce in stellar spectra, the interstellar lines, among the most prominent of which are the H and K lines of calcium in the far visible violet. An account has recently been published of the extensive research on the properties of these lines at Mount Wilson (for summary, see[9]), and throughout the text the limitations imposed by the Earth's atmosphere are apparent. Exposures are limited; hence higher dispersion in the spectra can only be obtained at the expense of brightness. The observer is therefore forced to select for his study (*a*) the brighter stars and (*b*) stars whose intrinsic spectra do not contain the same lines as the interstellar lines. Important conclusions have emerged from the present work. One is that the intensity of the H and K lines is proportional to the distance of the star; the use of this yard-stick to stellar distances is limited only by the exposure-time limitation. Where sufficient dispersion can be applied, the lines are shown to be complex, that is, composed of a number of different lines separated from each other by small wave-length shifts due to Doppler effect. Each one of these components is due to an individual cloud, and the number of components in each line is again roughly proportional to the star's distance. Further, the velocities of the clouds show that the more massive clouds have the smallest random velocities. The limit of dispersion is a serious handicap therefore to the study of the dynamics of the interaction between these interstellar clouds. Molecular lines due to interstellar matter also occur, and investigation of these lines is even more seriously affected by limited dispersion, and in fact, we know little more about these lines than that they exist. When the whole of the electromagnetic spectrum can be studied, new interstellar lines will appear, possibly indicating new interstellar elements. It is even possible that ultra-violet *emission* interstellar lines due to fluorescence excited by starlight may exist. Such an interesting prediction has been made, and if it should prove correct, valuable information may be obtained on the physical state of interstellar clouds.

A similar tug-of-war between intensity and dispersion is found is one form or another in most branches of stellar spectroscopy—and spectroscopy is the main-spring of modern astrophysics. In stellar physics, the possibilities of the lunar observatory are thousandfold; I have only time to mention one or two that immediately come to mind. For example, the known spectroscopic binaries will not only increase in total number, but will also individually be examined with greater accuracy, as smaller displacements will be measurable. Slower orbital velocities will be measurable, and hence wider doubles, and the gap between spectroscopic and photographic binaries may be filled. It may also prove possible to extend to the spectroscopic binaries the detection of "planetary" companions, as has been achieved already with two visual binaries.[8]

Again, stellar magnetism (which I have had cause to mention already this evening) provides a striking example. This important property of some stars was only recently discovered, and the fact that the discovery was made only by the use of the most rapid and powerful spectrograph available to astronomy (the coudé spectrograph on the 100-in. telescope), shows that the difficulty is not inherent in the stellar spectra, but in the effects of the Earth's atmosphere. The detection of the polarisation of the Zeeman components of the spectral

lines[8] required delicate and sensitive apparatus; even then it was not possible to separate the individual components, but only to detect different polarisations on different wings of the unresolved line.

With the complete spectrum available, the relationship between normal stars and the at present mysterious "point-sources" of radio emission[10] may emerge. Infra-red observations on the scale at present possible are planned, but they can reach only a very small way across the gap between the optical and radio wave-lengths.

Scattered light being limited, in a lunar observatory, to that due to imperfections of the optical instruments used, we could observe stars very close to the Sun. At present this can only be done during an eclipse. To make such observations it is important to measure the bending of light by the gravitational field of the Sun, which causes small displacements in stars observed very near to the Sun's limb. This effect, predicted by relativity theory, has been tested at eclipses, but the data is meagre and cannot be called satisfactory. Important as is the place held by relativity theory in modern physics and astrophysics, direct observational checks are few and delicate, and more direct quantitative evidence is desirable.

The mention of relativity brings me to the study of great distances, to the extragalactic nebulæ. The importance of being able to give long exposures is here apparent. On the Earth, when we reached the limit of the 100-in. telescope (this limit being set by night sky fogging) we knew a certain finite region of the universe. To double the distance to the furthest known nebula, a 200-in. telescope had to be built. With a 100-in. lunar telescope, to increase the distance we would merely have to increase the exposure time of our photographs,* a much more economical procedure. The effort spent on "seeing a bit more of the universe" is not just to pander to a desire for "big numbers." The problem of the structure of the universe as a whole ("metagalactic structure") depends upon our knowing as great a volume of the universe as possible. Mathematical cosmologies will rise and fall with the acquisition of new information. We are only just beginning to appreciate the interest attaching to clusters of nebulæ. These clusters show distributions similar to the distribution of density in an isothermal gas restricted by its own gravitation, an interesting demonstration of the unity of physical laws. And, of course, we shall hear more of the still vexed question of the red shift of the nebular lines.

I have tried with these hasty illustrations to show how the properties of the molecules within our own tiny atmosphere affect our knowledge of the universe to its farthest known bounds. Are there any means of counteracting these atmospheric restrictions without using rockets? It is difficult to say. Electronic stabilisers have been designed to compensate automatically for changes in the position of a stellar image,[16] but their efficiency has yet to be proved in practice; certain rather fundamental objections can be made to the designs at present proposed, but something on these lines will probably be developed in the relatively near future. Of the absorption effects, there would seem no other solution than to "get away from it all," but it would be unwise to make any predictions.

* With a limitation set by the zodiacal light as previously mentioned.

Having reached the bounds of the universe in this discussion, I shall go no farther, for indeed I have gone far enough. While the lunar observatory may lie, perhaps, on the edge of the forseeable future, observations from the planets lie too far ahead for present consideration. This is not the only reason for my not examining their possibilities to-night; a more cogent reason is that I do not think that if ever such possibilities bear fruit, they will contribute vastly to our astronomical knowledge. For the importance of the lunar observatory, as I hoped to show you to-night, is not that it is on the Moon, but that it is outside the Earth's atmosphere. True, from planetary visits we may learn more of the constitution of the individual planets, but we would learn little new of the stellar systems that occupy the major energies of students of astronomy.

The more specific part of my discourse is now complete, but I would be leaving my task unfinished if I did not try and give a more general picture of the way in which the "new astronomy" fits in with the "old."

One approach to this problem has already been made by Zwicky in his recent Halley Lecture. He calls it the "morphological" approach. The whole vast domain of astronomy and astrophysics is considered as a unity, and the aim of morphological astronomy is, in Zwicky's words, to "achieve a schematic perspective over all of the possible solutions of the given large-scale problem." All such possible solutions are represented by a matrix, in which the individual elements represent individual components of an observation or conclusion. For example, one column will be a list of all conceivable types of instruments (in theory), another the location of these instruments, another the objects of observation, etc. Any combination of elements make a theoretical observation, but only a limited number will be practically feasible. The importance of the development of astronautics is thus seen to be the rendering feasible of a whole new block of these elements of the giant matrix. For further interesting speculation on these lines, readers should consult Zwicky's very readable lecture.[17]

Another, perhaps more straightforward, approach is the historical one. In the history of practical astronomy we can trace a few important landmarks. First would come the invention of the graduated circle, whose origin is obscure. Second would come the invention of the telescope about 1600 A.D. The application of photography and spectroscopy in the latter half of the last century brought with it the rise of modern astrophysics. Perhaps the next landmark is already upon us, the application of radio and electronic techniques to astronomy. But the application of astronautics will be a landmark of double significance. Not only will it herald a new power of observation, but it will also, however slowly, bring astronomy (at once the oldest and the youngest of the sciences) from observation to experiment.

We can put these ideas into perspective by likening Man to a very young baby. He has spent most of his life in the blissful unawareness of sleep. A short while ago he opened his eyes, saw the cot in which he was lying, and played with it a little. Just a moment or so ago he looked outside his cot, and realised that he was in a room full of mysterious objects—he wonders what they are. He is just thinking, in his childish way, of reaching out and touching the nearest

of these objects—that is the stage of Man's development to-day. In his youth, let alone his maturity, will he not find it difficult to appreciate the problems that now beset his childish mind?

If we may speculate further with Zwicky, we may forsee, not only experiments on celestial bodies, but experiments *with* them. In his words again:

> "An extrapolation of these applications which lies in the line of morphological thinking, and which we might as well visualise cold-bloodedly, since it appears inevitable, is the *reconstruction of the universe* . . . (the italics are Zwicky's)."
>
> "In the wake of the realisation of large-scale nuclear fission, there will, no doubt, follow plans for making the planetary bodies habitable by changing them intrinsically and by changing their positions relative to the Sun.* These thoughts are to-day nearer to scientific analysis and mastery than were Jules Verne's dreams in his time."

(Did not Omar Khayyam, too, dream that if we could:

> ". . . grasp this sorry scheme of things entire,
> Would we not shatter it to bits—and then
> Remould it nearer to the Heart's Desire!" ?)

It is clear that what I have said to-night touches only the fringe of the impact of astronautics on astronomy, only one field of human thought. But though it may be only the start, it is farther than we can with certainty see in detail.

I do not suppose that I have shown any particular clarity of vision in the matter. Most that I have said to-night can at best hope to be condemned, in the cold light of posterity, as trivial, but if I have been able to show, however imperfectly, something of the potentially revolutionary importance of rocket research to that field of human endeavour in which I have a particular interest, then my effort has not been wasted, and I can leave the judgment to posterity, comforting myself in the thought that it will not be very long before its speculations have been overtaken by practical achievement. And—

> "When Man has conquered all the depths of space, and all the mysteries of time, then will he be but still beginning!"†

* May I, in a not-too-serious parenthesis, express the hope that a solution to the problem of the origin of the solar system is found before some over-zealous practical mathematician begins "cooking the data."

† H. G. Wells, *The Shape of Things to Come.*

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THE RESEARCH SCENE—2

By K. W. Gatland

A.4 Rocket Development in America

The development of the A.4 rocket for altitude sounding has been proceeding under the auspices of the United States Armed Forces since early in 1946. At that time, the Army Ordnance Department had recently completed plans to launch a series of 25 captured German A.4s. for military appraisal, firing to take place at the Army's White Sands Proving Area in New Mexico. The possibility of improving the utility of the vehicle by using the war-head space to carry instruments was discussed in January, 1946, and the work of producing a suitable instrument compartment for the rocket was subsequently undertaken by the Naval Research Laboratory.

The Johns Hopkins University Applied Physics Laboratory at Silver Springs, Md., was assigned to perform basic scientific studies of the physics of the upper atmosphere and to provide instrumentation. Specific investigations were to include solar spectroscopy, measurement of the solar constant, studies of the ionosphere, cosmic radiation, pressure and constitution of the atmosphere, and of the flight properties of rockets, including tests of surface temperatures, etc.

The High-Altitude Research Group of APL was organised in late February, 1946. The Laboratory had at its disposal, on the average, every fourth A.4 with other participating agencies using the intervening rockets. A later extension of the Army's firing programme to include 75 A.4s, however, greatly increased the research possibilities of this particular series of experiments.

While APL participation in the A.4 programme was still in an early planning stage, conversion of rockets was initiated by the Aerojet Engineering Company and the Douglas Aircraft Company parallel with the development, specifically for altitude research, of a series of smaller bi-fuel rockets. A Bureau of Ordnance contract for the design, manufacture and testing of 20 Aerobee rockets was awarded in May, 1946.

A.4 Characteristics

Carrying over 19,000 lb. (8,626 kg.) of fuel and oxydiser, the A.4 has a firing time of 60 seconds. With a combustion chamber pressure of about 15 atmospheres at 2,500° C., the exhaust velocity is approximately 6,560 ft./sec. (2,000 metres/sec.), the thrust, 28 tons (28·4 tonnes). Acceleration rises to 6 g. (with a velocity of 5,000 ft./sec. (1,525 metres/sec.) just before burn-out, which occurs at an altitude of 100,000 feet (30,500 metres).

Altitudes of between 65 and 114 miles (104·5 and 163·4 km.) have been attained with flight times averaging 8 minutes and periods of 4 to 5 minutes have thus been spent above the furthest reach of sounding balloons which, at present, is 26 miles (41·8 km.).

A block-house, with reinforced concrete walls 15 in. (380 mm.) thick, is located 1,000 ft. (305 m.) from the launching point to shelter personnel during firing. This is the nerve centre for the entire launching operation, where starting circuits for the rocket motor and for the instrumentation all terminate. Communication is maintained between the block house and all observing and recording stations located at various points in the proving ground.

The trajectory of the A.4 is controlled by a gyro-stabilising mechanism in the rocket and limited, if necessary, by a remote control fuel cut-off system. Fuel cut-off is effected when a multiple channel radio in the rocket receives the appropriate command. This system has been used on certain flights when an A.4 did not follow a safe trajectory.

Location of Instruments

The instrument-head provides 19·6 cu. ft. (0·55 cu. m.) of space. To make optimum use of this requires careful design and placement of equipment, and has resulted in the use of a "pyramid" frame with compartments into which are fitted the various electronic units with the smaller and lighter units at the top. From time to time, some space in the aft section of the rocket has been made available for instrumentation and though high temperature and vibration are encountered due to the close proximity of the rocket motor, the possibilities for recovery of instruments installed here have proved relatively good.

Factors in A.4 Experimentation

The following paragraphs contain a statement of some of the more important of the exacting conditions involved in A.4 experimentation, and of the techniques used to ensure correct operation of the rocket.

(1) All equipment carried in the A.4 is affected by the acceleration of the rocket. The maximum acceleration due to propulsion is 6 g., and the equipment has been designed to operate under this condition. It has been estimated that the rocket undergoes a 17 g. lateral acceleration towards the end of the flight due to vibration. A shake-table and a centrifuge have been used to simulate the operation of equipment under various accelerations.

(2) Another situation encountered in experimentation at high altitudes is the breakdown of air as an insulator at low pressures. The solution

of this problem has been to maintain the interior of the instrument-head at atmospheric pressure by means of gaskets on the base and access doors of the compartment. Cable connections are brought through the base by means of pressurised receptacles and plugs, which are covered by brass cylinders and packing glands to form an air-tight seal. It is not considered necessary to pressurise the top section of the compartment where such equipment as the solar spectrograph is contained.

(3) It has been calculated that the maximum local skin temperature. encountered in the instrument-head will be at the nose tip and may be of the order of 500° to 600° C. Due to the high heat capacity of the rocket and to the relatively short time in which the rocket encounters appreciable air friction, it appears that the temperature rise in the instrument-head is not great and that no special precautions are needed to ensure operation of electronic equipment. It was noted that the paint on the outside of the rocket fired on July 30, 1946 was only slightly blistered, indicating relatively moderate skin temperatures. The Geiger tubes used in the flights have been tested for reliable operation. It has been found that they will operate successfully at temperatures as high at 100° C. and as low as 10° C., a range that exceeds all temperatures to be expected in flight.

(4) Recovery of data has been an important feature of the A.4 programme. Two parallel methods have been used, one being telemetering (a 60 channel system is now in use) and the other, physical recovery of recorders within the rocket.

An additional problem of importance is that of determining the operability of equipment during flight so that the data obtained may be interpreted correctly, and so that any portion of the instrumentation which fails may be redesigned as required. A method of calibrating the Geiger counters during the flight by periodically exposing them to Beta particle radiation from a radioactive phosphorus source has been used to establish the operation of the counters as well as the electronic sources.

(5) Weight allowances for instrumentation are not critical. It is necessary for stability reasons, however, to have the total weight of the loaded instrument-head in the neighbourhood of 2,200 lb. (998·8 kg.). Lead counterweights are added to bring the gross weight to within several hundred pounds of this figure. The location of the centre of gravity of the instrument-head is not critical and no particular consideration was given to this factor in designing the instrumentation.

(6) The position of the rocket in flight is important. Roll is to be expected, and has been induced in some cases to increase stability. The resultant period of roll has varied within the range of 6 to 40 sec. Tumbling in flight, with a period of about 50 sec., is typical after burn-out.

(7) The maximum period available for obtaining data is naturally significant in planning A.4 experiments and is limited by the rocket's short flight time. The usable time is reduced by explosive separation of the

instrument-head, a technique used to break the A.4 into two aerodynamically unstable parts to lower the terminal velocity of the rocket and to facilitate recovery. No data is secured after separation of the instrument-head from the hull. The time of flight from launching to "blow-off" has been set at 5·5 minutes, by which time the rocket is over the peak of the trajectory on a flight to an altitude of 100 miles (161 km.) and yet is still above the ground on a shorter flight of, say, 60 miles (96·5 km.).

Tracking

Tracking of the A.4 rockets and reduction of trajectory data is conducted by the Ballistic Research Laboratory of the Aberdeen Proving Ground, the Signal Corps, and the New Mexico College of Agriculture and Mechanic Arts. Measurements made by BRL include position, velocity, and acceleration as functions of time, aspect, point of impact, and time of flight. The Laboratory also provides time signals on both wire and radio communication channels for use by the various observers in co-ordinating measurements with the trajectory data. Radar, radio, photographic, and visual equipment are used in making trajectory measurements.

Telemetering

The problem of recording data was recognised early in the A.4 programme when a telemetering system, designed by the Rocket Sonde Section of the Naval Research Laboratory, was installed in a rocket fired on July 30, 1946. Although physical recovery of instruments after impact has proved useful, it has not been completely reliable, particularly in the early phases of the programme.

The Naval Research Laboratory telemetering service has been highly successful. Briefly, it is a time-modulated pulse system which delivers higher peak power at a lower average power consumption than a continuous carrier system. It operates at about 1,000 mc./sec., a frequency high enough to penetrate the ionosphere. The data voltages from experimental equipment are converted into time intervals defined by voltage pulses. These pulses are transmitted from the rocket and received by ground stations which decode and record the data. Several methods of recording the voltage data are used, including a record on a moving strip of photographic paper made by Hathaway magnetic string oscillographs, and a motion picture record of the meter panel. A wire recording is made of the signal taken off before the decoder as a precaution against decoder failure. The master time signal is impressed on each of the various recording devices.

Physical Recovery of Equipment

Certain types of data (*e.g.* solar spectra) are not readily adaptable to transmission by the telemetering system. It is, therefore, desirable to make records within the instrument-head during flight and to recover these records after the rocket has returned to earth.

After a flight on May 10, 1946, an extensive search of the impact crater and surrounding area failed to discover any of the rocket instrumentation.

Two possibilities for increasing the chances for physical recovery after impact seemed worthy of investigation. The first was to render the rocket unstable when it re-entered the atmosphere and thus reduce its terminal velocity. The second possibility was to eject equipment near the end of flight and reduce its velocity by a drogue device. The use of parachutes to lower all or part of the rocket was also considered. It was felt, however, that the development of parachutes to operate under the exacting conditions involved would be a lengthy process and that certain portions of the equipment could be designed sufficiently rugged to withstand a relatively high impact velocity.

It was thought that if the A.4 were separated by explosion as it entered the atmosphere, the velocity on impact would be considerably reduced since the pieces would possess less aerodynamic stability than the whole rocket. Consideration was given to the following methods of reducing aerodynamic stability:

(*a*) Blow-off of tail-fins with a small amount of explosive to render the rocket so unstable that it would break up through inherent structural weakness.

(*b*) Separation of the rocket by explosives placed at the junction of the control compartment and fuel section.

(*c*) Separation of the instrument-head from the hull by a small amount of explosive placed on the struts adjacent to the base of the compartment at the top of the control section.

Of the three, the third method seemed more likely to succeed in practice and it was adopted. The technique has since proved a satisfactory and dependable means of lowering the terminal velocity to a few hundred feet per second, sufficient to achieve reasonably good physical recovery of recorded data such as exposed spectrographic and motion film protected by thick-walled steel cassettes.

The author is indebted to the Johns Hopkins University Applied Physics Laboratory for information supplied and contained in their Report No. 81 in the "Bumblebee" series.

A Critical Review of

"CAN WE FLY TO THE MOON?"

J. Himpan and R. Reichel[1] have reviewed the possibility of firing instrument-carrying rockets on to the Moon and of building manned rockets capable of making return flights to the Satellite. They conclude that the first project would be possible, but that the cost of developing such rockets would be excessive. As to the manned lunar rocket, they conclude here, as a result of somewhat superficial arguments, that such a vehicle is impossible.

The design study given by these authors for an instrument-carrying Moon rocket, is based upon the use of a bipropellant mixture of fuel oil and tetranitromethane (Chamber temperature = 3,260° K.), which they consider to be the best possible combination on the basis of the high density and high boiling

points which facilitate jacket cooling. A three step rocket is considered, with the following performance characteristics:—

Step 1

Initial mass	= 50,000 kg.
Thrust	= 100,000 kg. for 90 sec.
Step mass ratio	= 5·5 (*i.e.* ratio of loaded mass of this step, plus mass of subsequent steps, to this quantity minus propellant mass of this step).
Chamber pressure	= 20 kg./cm².
Exit pressure	= 0·8 kg./cm².
Effective exhaust velocity	= 2·16 km./sec.

Step 2

Initial mass	= 5,000 kg.
Thrust	= 10,000 kg. for 106 sec.
Step mass ratio	= 5·0
Chamber pressure	= 20 kg./cm².
Exit pressure	= 0·1 kg./cm².
Effective exhaust velocity	= 2·61 km./sec.

Step 3

Initial mass	= 500 kg.
Thrust	= 1,000 kg. for 107·5 sec.
Step mass ratio	= 5·26
Chamber pressure, Exit pressure, Effective exhaust velocity	As in Step 2.

Himpan and Reichel do not consider hydrogen and oxygen to be a suitable propellant combination, on the grounds of the low density and alleged impossibility of cooling the motors with either of these substances. As a result, the ratio of payload to take-off mass is less favourable than those calculated by Malina and Summerfield,[2] who do not dismiss the hydrogen/oxygen mixture so lightly. The 50 tonne rocket of Himpan and Reichel would carry a payload of 10 kg.

The authors go on to consider the possibility of a circum-lunar rocket based on chemical propellants and show that the initial masses of such rockets assume fantastic proportions. This is an indisputable fact, but the possibility of circumventing this difficulty, by the use of orbital refuelling, is not considered by Himpan and Reichel.

The use of nuclear energy is examined, in this paper, with particular reference to the employment of a working fluid which can be heated by the nuclear energy sources and expanded through the conventional nozzle. The authors choose water as their working substance and assume an initial temperature of 3,370° K. with a pressure of 20 kg./cm². It is difficult to understand the authors' choice, since this temperature could be obtained by burning hydrogen

and oxygen at the same pressure. Under these circumstances the use of nuclear energy sources would be completely superfluous. Of course, the storage density of water is considerably better than that of the hydrogen/oxygen mixture but this would certainly be largely offset by the greater mass of any conceivable nuclear power unit. It is not surprising, then, that the payload ratio for an instrument-carrying atomic rocket, which Himpan and Reichel derive, is little better than that for their chemical rocket, and their subsequent dismissal of the possibility of a circum-lunar rocket is therefore inevitable. However, the authors' statement that little improvement could be gained by the use of any other working fluid is not justified. Obviously the use of hydrogen as a working fluid would reduce the required mass ratio by a very large factor. In fact, the value for H_2O would be approximately the cube of the value for H_2! In the circumstances, one cannot accept the authors' arguments against the possibility of building a circum-lunar rocket based on the use of nuclear energy in this manner.

The remainder of the paper is devoted to the possible use of "pure" atomic energy, instead of the "diluted" form utilised in the working fluid method. The authors conclude, and rightly, that the use of nuclear energy in this way would lead to fantastic power dissipation in the case of a motor with high thrust. However, the desirability of using nuclear energy in this manner is not discussed. So long as nuclear fuels are much more scarce and infinitely more expensive than ordinary materials, then the conservation of fuel would be of prime importance. Under these circumstances the use of the intermediate working fluid would be essential. To illustrate this point, we can take as an example the use of a fission fuel (*a*) with a working fluid giving an exhaust velocity of about 10 km./sec.; (*b*) "raw" with an exhaust velocity of about 10^4 km./sec. It can be shown that case (*b*) would require the expenditure of about 100 times as much nuclear fuel as case (*a*) to propel a given payload around the Moon. Thus the discussion of the use of "pure" atomic power for a moon-rocket is irrelevant, so long as nuclear fuels remain scarce in comparison with possible working fluids, even apart from the important power dissipation consideration. In conclusion, it must be contended that the inference drawn by Himpan and Reichel, from such unfavourable examples as they have chosen to consider, that interplanetary flight is not a practicable proposition, cannot be accepted. The ultimate success of space-flight must rest on the combination of a number of circumstances, all of which will eventually become possible. Among these may be mentioned: the use of more favourable design conditions than those considered by Himpan and Reichel, the adoption of orbital refuelling techniques and the setting up on the Moon of a plant capable of producing rocket propellants so that the difficulties of impossible mass-ratios can be removed. (It is conceivable that this latter aim can even be achieved by the use of one-way rockets.) The devotees of the idea of interplanetary flight need not therefore be dismayed by the pronouncements of these two authors.

L. R. S.

REFERENCES

(1) *Am. Journ. Phys.*, **17**, pp. 251–263, May, 1949.
(2) *J. Aero Sci.*, **14**, 471, 1947.

NOTES AND NEWS

New Satellites

A second satellite of Neptune, of about magnitude 19·5, was discovered by Dr. G. P. Kuiper at McDonald Observatory on May 1, 1949. Preliminary calculations give the new object a circular orbit with a radius of about 5 million miles. (Triton, the other known satellite, is of 13th magnitude and has an orbital radius of only about 220,000 miles.) The orbit is inclined 5° to the plane of the ecliptic with a period of about 2 years, and the size of the satellite has been estimated from its photographic magnitude to be about 200 miles.

The recently discovered 5th satellite of Uranus has now been named *Miranda* by its discoverer, Dr. G. P. Kuiper (see *Journal*, p. 170, July, 1948). Its orbital motion is roughly circular in the same plane as the other satellites, with a period of close to 33 hours, 56 minutes.

Nominations for Council, 1949–50

In accordance with the provisions of Article 15 of the Society's Constitution, one-third (*i.e. four*) members of the Council will retire from office at the Fourth Annual General Meeting, to be held at St. Martin's School of Art, 107, Charing Cross Road, W.C.2, on Friday, December 9, 1949, at 6 p.m.

Nominations are invited from members for election to the Council for next session. (Under the provisions of Article 13, the Council may now contain three *Members* of the Society.)

Signed nominations should be forwarded to the Secretary as soon as possible, and in any event not later than October 28, 1948.

Voting forms will be prepared and forwarded to all members for completion and return before the date of the meeting.

B.B.C. Talk

It is hoped that many members heard the interesting talks "Is There Life Elsewhere in the Universe?," broadcast in the B.B.C. Third Programme recently, and reprinted in *The Listener* for July 21, 1949. The two speakers were Fred Hoyle and C. D. Darlington, respectively well-known as cosmogonist and geneticist.

Mr. Hoyle submitted that the theories of the formation of the Solar System, largely due to the Cambridge mathematician R. A. Lyttleton, are now accepted as almost certainly correct. These require that the Sun be assumed to have been, at one time, a member of a double star, the other member of which became a supernova and formed the planets from its debris. He proceeded to argue that, since supernovae were observed at the rate of about one per galaxy per 500 years, and our own galaxy was about 5,000 million years old, there must have been about 10 million supernovae in this galaxy alone within its life. About half of these would have occurred in double star systems (since double stars were nearly as common as single ones), and therefore there must be nearly 5 million planetary systems in our galaxy. There were also some 100 million *other* galaxies to be considered!

In Mr. Hoyle's opinion, only Mars was likely to be an abode of life in our Solar System, apart from Earth, and even on that planet it was likely to consist only of a low form of plant life. It therefore seemed to him probable that only perhaps one in ten of all planets would have physical conditions sufficiently like those on Earth for intelligent life to have developed, but this still left an immense number of possible worlds in any one galaxy, and, of course, a still greater number in the whole universe.

Mr. Darlington tended to base his remarks on the same assumption as Mr. Hoyle—that the physical conditions for intelligent life must necessarily approximate to those on Earth. Indeed, he concluded (after an interesting discussion of the bio-chemistry and evolutionary processes of terrestrial life forms) that "pseudo-men" existing elsewhere in the universe would probably be very like ourselves, and might have developed rather similar cultures. We are sure that he did not mean his listeners to take him seriously when he observed "The idea of a creature more intelligent than ourselves is of course inconceivable," but he almost certainly did when he stated that it was extremely improbable that we should ever have "the opportunity of meeting our inter-galactic friends—or enemies—in order to settle these exciting academic questions."

Of course, we cannot agree with Mr. Darlington on this latter point, and it also seems to us that it is a rather parochial viewpoint to adopt to rule out the possibility of extra-terrestrial life existing under physical conditions vastly different from those on Earth. Neither speaker considered the possibility of life based on systems of body-chemistry quite different from our own.

It is most interesting to compare this British radio talk with those given last December by the N.B.C. in America, and which were reviewed by E. G. Ewing in the Winter, 1948–49 (Vol. 3, No. 3), *Journal of the Pacific Rocket Society*. The rather conservative biological approach was common to both, as also was the conclusion that a very large number of planetary systems probably existed in the universe—although this latter conclusion was arrived at by quite different theories of planetary formation, as between the American and British experts.

U.S. Rocket Range

In May of this year, the U.S. Congress authorised the expenditure of 75 million dollars on setting up a proving range for guided missiles, with a launching site on Florida's east coast. The missiles (rockets or jet propelled) will be fired out over the South Atlantic, with a maximum possible range of observation of 3,000 miles in the early stages of the project. Later this may be extended to 5,000 miles, and the cost may rise to 200 million dollars. Discussions with the British Government are in progress with regard to the establishment of radar tracking stations and other technical observation points in the Bahamas.

Nuclear Testing Station

According to *Time* for April 11, the American Atomic Energy Commission has announced that the first United States nuclear reactor testing station will be built (at a cost of 500,000,000 dollars over the next ten years) on a 400,000 acre site south-east of Arco, near Pocatello in the State of Idaho. It will become the

chief establishment for developing industrial atomic power units, including such projects as ship and aircraft propulsion.

The area concerned is described as being in the desert region of the Big Lost River Valley, "20 miles from the Craters of the Moon." We hope the latter reference has some symbolic significance, in connection with the future activities of the Arco station.

An Interesting New Asteroid

Dr. S. B. Nicholson and Dr. R. S. Richardson, using the new 48 in. Schmidt telescope at the Mount Palomar Observatory, have discovered a new asteroid, about a mile in diameter and approaching within 8,000,000 miles of Earth. The body is unique in possessing an orbit of great eccentricity, which (during its period of about 360 days) takes it from inside the orbit of Mercury to beyond that of Mars—its extreme distances from the Sun being 22 and 156 million miles. It is thought that observations of the perturbation of the asteroid may yield new data on the mass of Mercury.

Time newsmagazine quotes Dr. Richardson (who is a B.I.S. member) as saying: "But an asteroid is rather like a concerto. It has no real practical value." We can agree with this statement at least to the extent that any hope of using this peregrinating planetoid for hitch-hiking across the Solar System is doomed to disappointment—see p. 80 of the March, 1949, *Journal*!

G.f.W. Conference

At their 1949 Summer Meeting, the members of the new German inter-interplanetary society, the "Gesellschaft für Weltraumforschung" (G.f.W.), passed the following resolution:—

"The development of the big liquid fuel rocket has advanced so far that the question of space flight now arises and its practicability can be confidently affirmed.

"The rocket is not only a weapon, but also an instrument of peaceful research. The G.f.W. therefore considers one of its most important tasks to be the emphasis of the peaceful possibilities of space travel and the promotion of the idea of space flight as a new means of research.

"The drive towards interplanetary space and future research on space flight are international tasks. Co-operation between scientists and engineers of all nations culminated in the present successful position.

"The G.f.W. therefore recommends an international meeting of all societies for rocket development, interplanetary travel and space research, to foster friendly relations and a successful exchange of knowledge, and to explore the possibilities of forming an international association for astronautics."

H. Gartmann
H. H. Koelle
June 22, 1949. (for the Board of Directors, G.f.W.).

The above resolution was sent to the B.I.S. with the following letter of the same date:—

GENTLEMAN,

On the occasion of its 1949 Summer Meeting at Stuttgart, the G.f.W. sends greetings to the B.I.S. in London, and confirms its wish to maintain the close friendly relations which have so far linked the two societies.

Especially, the G.f.W. sends thanks for the material which the B.I.S. has supplied, and the interest which it has always shown in the progress of astronautics in Germany. The honour which has been conferred on the G.f.W. societies' Honorary President, Prof. Hermann Oberth, by making him the first Honorary Fellow of the B.I.S., will deepen the co-operation.

To serve this aim by its own part, the G.f.W. at Stuttgart has appointed Mr. A. V. Cleaver, Chairman of the B.I.S., as Honorary Member of the G.f.W.

Looking forward to further successful co-operation.

We remain,

Yours sincerely,

H. Gartmann.
H. H. Koelle.

Further and more detailed proposals have been received from the G.f.W. regarding the international meeting and society suggested in the Resolution. It is proposed that London should be the venue for the conference, and our views were requested on this point and the other questions involved.

The B.I.S. Council has replied to the G.f.W., thanking them for their good wishes and the honour conferred on our Chairman, and expressing general agreement in principle with the other proposals made. It was felt, however, that the desirable objects aimed at would be best served by not attempting to rush matters. Discussions on the proposed international meeting should be initiated forthwith, not only between the G.f.W. and the B.I.S., but also between other comparable bodies. As a first step, the possibility of forming an international federation of autonomous national societies should be explored. After preliminary discussions on these matters, it would indeed be profitable to hold the proposed international conference in a year or two's time, if a large measure of agreement were found between the interested parties, and we would welcome this taking place in London.

We shall report on the progress of these discussions in the *Journal* from time to time, and would welcome correspondence from members giving their views.

The G.f.W. societies of the three West German Zones have just published the first issue of their Journal; it contains a letter of good wishes from the B.I.S., sent by our Chairman, together with one from Dr. Ing. Eugen Sänger in Paris. Dr. Sänger also contributes an article, and in the 20 duplicated pages of the Journal, there are others by Messrs. Koelle and Kaeppeler, and a note on the late Dr. R. H. Goddard by Willy Ley. The proposed technical programme of the G.f.W. is described, the first task to be undertaken being the revised calculation of the practicability of space flight using the latest data. Prof. Dr. H. Siedentopf will manage the Consulting Council of the G.f.W.; Herr Koelle

is Secretary and Dipl-Ing. Gartmann is Technical Director. At the Stuttgart Summer Meeting, other Honorary Members of the G.f.W. appointed, in addition to Mr. Cleaver, were: Dr. Eugen Sänger, Ing. Guido von Pirquet, Otto Willi Gail, Willy Ley and Prof. Wernher von Braun.

News Flashes (Without Comment)

(1) Mr. James T. Mangan of Chicago has ordered the Army, Navy, Russia and other nations not to attempt any trips to the Moon. Last December he founded a nation called "Celestia," which includes everything beyond the Earth, and says, "no passports will be issued until my nation is recognised." His claim is based on the fact the he "filed his charter with Cook County recorder of deeds."

The new nation's charter makes no provision for voting but guarantees freedom of the press. (*New York Herald Tribune* (Paris edition), July 4, 1949.)

(2) "I cannot have my holiday until the end of September and then I want to take my wife to the Sun. We would prefer to fly. Have you any suggestions?" (*Sunday Times.*)

Well, you could try the Interplanetary Society!
(*Punch*, July 13, 1949.)

(3) "Like Donald, I have designed space ships and have suggestions to make."—Michael Guest, aged 15½. (*Daily Mirror*, July 23, 1949.)

(4) "Members of the rocket society (Canadian) said that the moon ship would have to contend with danger from meteors. 'There would have to be judicious steering to prevent disaster,' they said." (*Evening Standard*, July 16, 1949.)

(5) "Mr. R. L. Farnsworth (of the United States Rocket Society) said that the Canadian Rocket Society are 'just a bunch of amateurs who have got wrapped up in their own dreams.'" (*Evening Standard*, July 19, 1949.)

(6) "Scientists say that life on Mars is practically impossible.
Just as it is here." (*Answers*, July 30, 1949.)

Book List

A new and revised print of the Society's *Book List* is now available, and any members who desire to receive a copy should apply by postcard to the Secretary.

Errata

We regret that the following mistakes have crept into print:

(*a*) Mr. Shepherd's address (p. 20, January, 1949, *Journal*) should read 28, Avon Road, Chilton, *Berks*.

(*b*) Page 239, Nov., 1948, Table III, Row 4, should read "Helium He 4·00 0·14 — 269°."

Westcott and the B.I.S.

The R.A.E. Rocket Propulsion Department at Westcott (near Aylesbury, Bucks.), which is, of course, the official Government establishment for rocket research, publishes a monthly magazine called *Venturi*, for circulation among its staff. This amusing little paper is mainly devoted to items of local news, gossip, etc., with many wisecracks directed at the various personalities on the station. In the July issue (Vol. 2, No. 11), we were interested to find the following true story, which suggests that in some quarters confusion may exist as to what body is responsible for British rocket development:—

Accuracy

Customer: "Good afternoon, have you a copy of Sutton's *Rocket Fundamentals*, please?"

Bookseller: "Yes, sir. You know, there's been quite a run on these lately."

Customer: "Really?"

Bookseller: "Yes, the British Interplanetary Society at Aylesbury have bought quite a few."

Customer: "British Interplanetary Society at Aylesbury? Don't you mean the Government Rocket establishment near Aylesbury?"

Bookseller: "Er—oh yes. I believe they are there, too."

Acknowledgment

The Council acknowledges with thanks receipt of a copy of *Physik der Weltraumfahrt*, kindly donated by Herr Heinz Gartmann.

KNOW YOUR COUNCIL

A. E. SLATER, M.A., M.R.C.S., L.R.C.P. Born 1894, and was educated at Abbotsholme School, Cambridge University, and St. Thomas's Hospital. Took Cambridge B.A. degree in Mathematics and Music (obtaining a 1st Class degree in Music), and then took up medicine as a more certain means of livelihood. Qualified as a medical practitioner in 1922, and joined the Fever Hospital Service of the L.C.C. in 1924.

Dr. Slater has been interested in astronomy and aviation from a very early age, and later his interest embraced also meteorology, gliding and soaring flight. The last two found scope when gliding was revived in England in 1930, for in that year Dr. Slater became the first British Glider Pilot to obtain a gliding certificate without previously flying aeroplanes. He accepted a spare-time post as editor of *Sailplane and Glider* in 1933, but this soon grew to such proportions that he had to give up his medical career in 1936 and start a new career in journalism! However, he subsequently returned to medicine during the war, this time with the L.C.C. Mental Hospitals Service.

Dr. Slater joined the Society in 1945 and became editor of the revived B.I.S. *Journal* in 1946, but was forced to give it up after editing three issues owing to pressure of other work.

At present, he is gliding and meteorological correspondent of *The Aeroplane*, and also the gliding correspondent of *The Times*. He has written historical and meteorological chapters in several gliding textbooks and in 1945 prepared a paper on the dispersal of insects by vertical currents. In 1944 he was elected to the Council of the Royal Meteorological Society.

T. R. F. NONWEILER, B.Sc. Born 1925 and educated at Bethany School, Goudhurst, Kent, where he was a student teacher from 1940–41. Took his degree in honours school of mathematics at Manchester University in 1944. Entered the Royal Aircraft Establishment at Farnborough as Scientific Officer, and was for a time engaged upon flight research of jet-propelled aircraft. Mr. Nonweiler was one of those engaged in the investigation of the German V.2 project, and later turned his attention to the problems associated with the application of jet and rocket engines to aircraft propulsion. At present he is engaged on fundamental research into aircraft design and airflow problems at supersonic speeds.

Mr. Nonweiler is the author of several papers on high-speed flight, and his new book, *Rockets and Jets*, written in collaboration with R. Smelt, M.A., is due to be published shortly. He has also broadcast on the problems of high-speed flight on a number of occasions.

P. E. CLEATOR. We have had some trouble in obtaining data for this short biography of the popular founder of our Society. The information which he sent contained a number of pertinent facts, but the manner of their expression tended towards the quixotic; some of the observations concerned will, no doubt, interest our readers, as throwing some light on the highly original Cleator character.

A request for his "exact" date of birth resulted in the reply: "Born Wallasey, Cheshire, June 7, 1908 . . . It was, I believe, a Sunday, which would account for my deep religious nature. I'm also informed that I entered this world at a most ungodly hour—around 1 a.m. or 11 p.m., I'm not sure which. Is all this exact enough? Or must I seek out the name of the midwife concerned?" He also suggested to our long-suffering Secretary that we describe him as: "Agnostic, sceptic and pacifist. . . . A one-time idealist whose disillusionment is now complete," and attempted to satisfy a further request for his picture with one of a Mr. Stanley, recently much in the news. Of the photograph subsequently obtained (and which is reproduced here), he wrote: "May God forgive the camera; surely it *has* lied?"

Educated at Wallasey Grammar School, Phil Cleator still lives in this district, where also is situated the family business (engineering contractors) which he runs. He is an honorary member of both the American and Pacific Rocket Societies, and was once British delegate to the German E.V. Forschrittliche Verkehrstechnik.

In 1933, he founded the British Interplanetary Society, edited its *Journal* from 1934 to 1936, and was its President until the Society moved its headquarters to London in 1937. He then handed over to Prof. A. M. Low, but remained a Vice-president and closely connected with the Society he had fathered. The new post-war B.I.S. naturally counted P. E. Cleator among its members; he returned to the Council at the 1947 election and was re-elected in 1948.

In 1936, he wrote the well-known *Rockets through Space*, the first British book on astronautics and an outstandingly good piece of popular scientific writing which did much to rouse interest in the subject in this country. He gave a B.B.C. talk on "Rockets" in 1937, and has been the author of some fiction and many articles on interplanetary matters, including a number of contributions to the post-war B.I.S. *Journal*. It is to be hoped that his stimulating pen and influence will long be active in this and other fields.

REVIEW

Voyages to the Moon

(By Marjorie Hope Nicolson. Macmillan, St. Martin's Street, W.C.2. 1948. pp. xvii + 297, 8 plates. 20s.)

Miss Nicolson is a professor of English at Columbia University; she has no specialised knowledge of science but is deeply interested in its impact upon literary imagination. This book is a study of the field in which that contact has been most fruitful: but many students of the interplanetary romance will be astonished to discover that Miss Nicholson finishes her investigation—apart from a brief epilogue—at the end of the eighteenth century. Those who imagine that, except for Verne, no writer of importance appeared in this field before Wells, will be annoyed or amused by Miss Nicholson's contention that after the Montgolfier ascent in 1783 the "cosmic voyage" suffered a slow decline and has now become so obsessed with technology that it has lost much of its pristine charm. But however much one may disagree with this thesis, *Voyages to the Moon*, will prove a mine of information and entertainment. It is hardly necessary to say that it is well-written, and within its self-imposed limitations it is in every respect superior to the only other book of its type, Bailey's *Pilgrims Through Space and Time*.

The history of the cosmic voyage is inextricably entangled with early dreams of flight, and both received an enormous stimulus from the great astronomical discoveries of the early seventeenth century. The invention of the telescope was responsible for one of the great liberations of the human mind; it made the Moon visible to men's eyes as a world in its own right, and revealed for the first time the true scale of the Universe.

John Wilkins, in 1638, listed the four possible means of flight as follows: "(1) By spirits, or angels. (2) By the help of fowls. (3) By wings fastened immediately to the body. (4) By a flying chariot." Miss Nicolson uses this classification as a convenient division for her book, and to a modern reader it comes as a considerable surprise to learn that the greatest of the "supernatural voyages" was written by no less a scientist than Kepler. The magical elements in the "Somnium," however, are concerned only with the voyage itself: when Kepler reaches the Moon his descriptions are strictly scientific, as far as the knowledge of the time permitted. According to Miss Nicolson,

> "Kepler transformed the old Lucianic tradition into the modern scientific Moon voyage. The weight of his scientific pre-eminence caused his little fictional work to be taken with utmost seriousness by the learned, and his sense of mystery—part of the mysticism that marked all his work—appealed greatly to poets and writers of romance."

It is, incidentally, of great interest to see what famous names in science and literature one encounters in Miss Nicolson's survey. Swift, Defoe, Huygens, Bacon (R. and F.!) Boyle, Hooke, Donne, Rousseau, Wren, Voltaire, Poe—all have been interested in flight in or beyond the atmosphere. It was only in comparatively recent times that such scientific speculating became no longer quite respectable.

Stories based on "flight by the help of fowls" and the use of artificial wings became very common as the old superstitions died and some factual basis was needed to replace the convenient "daemons" of earlier stories. With the notable exception of Godwin's *Man in the Moone*, however, these are more concerned with aero rather than astronautics, and the technically-minded reader will be more intrigued by the fourth category of stories, those employing "flying chariots."

It would be impossible to enumerate all the ingenious mechanical devices and plausible-sounding "engines" which authors have invented to elevate their heroes into the heavens. One may laugh at the vials of dew that Cyrano de Bergerac attached to his body so that he might be drawn towards the Sun: but perhaps the familiar "space-warp" of contemporary science-fiction will bear no closer examination.

The climax of this period of sheer literary inventiveness came, Miss Nicolson believes, at the close of the eighteenth century.

> "Nothing further seemed left for restless imagination. And, indeed, nothing *was* left to stimulate the kind of imagination with which I have concerned myself. We have reached the end of a chapter . . . for hundreds, even thousands of years, man had . . . let his fancy play with means of flight both credible and incredible. . . Those soaring souls . . . had recognised no barriers of time or space, no limitations of plausibilities. . . . But the future is upon us, a future in which no such untrammeled voyages of imagination . . . will continue to be possible. . . As the balloons of the Montgolfiers . . . symbolise a beginning, so they mark the end of a long period of trial and error. . . . They mark the end, too, of a peculiar form of literature. The cosmic voyage will go on, but after the invention of the balloon it suffers a change into something, I think, less rich and strange. Science has conquered fancy."

Notwithstanding this, Miss Nicolson gives brief accounts of a few more recent stories which seem to her to stand in the classical tradition, or at least to stem from it. These include Verne's *From The Earth To The Moon*, Wells' *First Men In The Moon*, and, in our own time, C. S. Lewis' *Out Of The Silent Planet*, which Miss Nicolson considers, not without justice, to be "the most beautiful of all cosmic voyages and in some ways the most moving." It is one of the very few modern stories, she considers, that retains some of the charm that technology has banished.

This continually recurring theme of Miss Nicolson's book—the idea that poetry and romance were exorcised by the arrival of exact science—surely will not bear close examination. Miss Nicholson's erudition and width of reading are both phenomenal, and one therefore hesitates to suggest that she has overlooked a large part of modern fantastic literature. But it is rather difficult to judge the extent of her reading in this field, as her chief references to the current scene are to "Flash Gordon" and the comic strips—surely of anthropological rather than literary interest. (One has, incidentally, a delightful mental picture of Miss Nicolson's desk at the beginning of each week being submerged beneath a pile of Sunday Supplements collected by her eager pupils.)

It is true that the "technical" story is now prominent, though perhaps not as prominent as Miss Nicolson imagines. Her judgment in such matters can scarcely be taken very seriously, for she makes the quaint remark that Dr. Weston's spaceship in *Out Of The Silent Planet* is "as elaborately realistic as you will find in any of the pseudoscientific pulps!" But stories have been written in the last few decades as full of poetry and wonder as any that earlier times can show. There is almost no "technology" in Stapledon's cosmic novels, but their vision and majesty has never been matched by any earlier writer. For sheer magic and beauty I do not believe the other-wordly tales of Lord Dunsany have been excelled, though it is true that few of them are in the direct "cosmic voyage" tradition. But many of the elements which Miss Nicolson (and this reviewer) most admires are in his tales, as also in the better stories of the American writers H. P. Lovecraft and Clark Aston Smith. The pity is that the work of modern authors is in danger of being submerged by the flood of trash by which many judge the entire *genre*. Luckily, good work is now being performed by such publishers as Arkham House in rescuing the best of such stories from oblivion beneath the rising sea of wood-pulp.

To lament that "science has conquered fancy" would in any case be to ignore the lessons of the past. Fancy cannot exist without science. The stories which Miss Nicolson cherishes could never have been written without the basic scientific discoveries which inspired them in the first place—as she herself points out. Men had to know that the Moon was a world before they could visit it: and the greater the field of exact knowledge the greater—not the smaller—the possibility of imagination becomes. Where the ancients only had a handful of planets and a single Sun, we have entire island universes full of wonders never dreamed of in earlier ages.

It is true that the frontier shifts: science overtakes earlier romances and obliterates them as the advancing tide smoothes down the sand. Five years ago fiction was still being written about the release of atomic energy: now only a few years are left in which to describe the first crossing of space.

There is nothing to regret in this. In many respects science has *liberated*, not enslaved, the fantasy writer. He need no longer devote the usual (and usually boring) chapter to his means of propulsion: this can be taken for granted and he can get on with the story, concentrating, for example, on the psychological or social implications of the subject. One result of this is that *characters* have made a shy appearance, here and there, in science-fiction: the stories are no longer enacted entirely by lay figures whose emotional reactions to extraterrestrial circumstances have changed remarkably little since Kepler's day.

Such writers as, for example, Ray Bradbury in *And The Moon Be Still As Bright* or *The Million Year Picnic* have made brilliant use of this new-found freedom. Although there is often far less "science"—pseudo or otherwise—in these stories than in tales written before this century, the best of them has a three-dimensional quality which the earlier stories wholly lack. Both have their own qualities and merits: but to prefer the older type to the exclusion of the new is like insisting that music was ruined when the sackbuts, hautboys and harpsichords gave way to the modern orchestral instruments. A. C. C.

CORRESPONDENCE

Professor Hermann Oberth

(We print the following much condensed version of a letter recently received, without comment, believing that it will be of interest to our members and that it represents a point of view which deserves to be given publicity. The opposite opinion has, as our correspondent states, frequently been expressed in print, and it is only fair that this should also be presented.)

In the November, 1948 *Journal* (p. 242), there appears the sentence, "Perhaps his undoubted genius lay in the fields of brilliant long-term anticipation and fundamental theory more than in the more mundane realm of practical engineering development." I cannot agree with this opinion.

I know that Professor Oberth has frequently been represented as a pure mathematician, or a theoretician not acquainted with practical engineering, but I believe that Oberth's genius for practical research fully equals his theoretical attainments. From personal observation I have seen his particular faculty of linking up theory with practice, and obtaining results in development with the most restricted means. I think that only narrow-minded specialists, or people working on the purely administrative side tend to level such unfounded criticisms. Such critics do not understand what it means to a scientist of such fame to work with modest facilities, without requiring elaborate research facilities, *e.g.* as existed at Peenemunde.

Oberth had to carry out many of his experiments at his own expense with never the use of costly testing plant, though this in itself did much to develop his self-reliance.

The opportunities offered to Professor Oberth for work on rockets by the German authorities were definitely unsatisfactory and unworthy of his gifts. Although in 1938 he was called to the Technische Hochschule, Vienna, it soon became apparent that the purpose of this was merely to prevent him from taking any similar appointment abroad. In spite of this, he carried out a number of experiments on his own, which yielded important results. When his activities in Vienna reached undesirable proportions, he was transfered to the Technische Hochschule, Dresden, where he could be more strictly controlled and was put in charge of "secret" development work for a fuel pump for what later became known as the V.2. Six months later Oberth learned incidentally that the device for which he had been made responsible had long since been superseded by other types developed at Peenemunde. This was yet another clear proof that he had been called to Dresden merely to keep him out of the way.

When Oberth finally came to Peenemunde, the V.2 was already very nearly completed and none of the men in charge was in any way interested in Oberth taking any part. He was thus again kept busy on subordinate work.

The first task allotted to him was the examination of all available patents with a view to possible uses in rocket technique. In actual fact not a single one of his recommendations was ever taken up experimentally, though many valuable ones were among them, some of which have only recently been adopted in America in similar form, simply because they represent the only correct solutions to the problems concerned.

A typical case of the deliberate elimination of Oberth by the Germans concerned his development of an AA rocket project, which was all the more important as it could also serve as a first step towards long-range, and even space rockets. This rocket was developed by Oberth on a new principle, surprisingly cheap in mass production, and very efficient in operation. The Peenemunde command took an absolutely negative interest in the project, as they had permission to build only liquid fuel rockets, and a solid fuel rocket of this type would have to be passed to some competing station. However, to keep Oberth quiet, he was ordered to submit drawings and reports, though he was not allowed to make any practical experiments, even though he made it clear that to explore the chemical and physical properties of such a novel type of rocket was a matter of prime importance. Oberth was given a draughtsman and a typist for this work, though only a week later the draughtsman was sent elsewhere for allegedly more urgent work, and the typist likewise had to do work for another department of the station for most of the time. Oberth thus had to send for his own private typewriter—this in an immense armaments station where there were at least 1,000 typewriters available. After one month, the drawing board placed at Oberth's disposal was taken from him. Hardly any one would have put up with rebuffs of this kind, yet Oberth finished his report, consisting of 150 pages and 63 drawings.

In December, 1943, Oberth was eventually posted to Westphalisch-Anhaltische Sprengstoff AG, WASAG plant, Reinsdorf to enable him to develop his powder rocket according to his own designs, but this was at a time when events had passed completely beyond the control of the Germans.

There cannot be any doubt, and it was repeatedly openly admitted, even by the Peenemunde command, and especially by von Braun, that Oberth's idea of a liquid fuelled rocket was the basic idea behind all the units developed at Peenemunde. This is brought out by the V.2, which in an overwhelming number of technical details is based on Oberth's inventions or conceptions. These calculations and observations were used at Peenemunde slavishly, whereas Oberth himself had long since made many improvements over and above those presented in his books. It was thus more than clumsy of the Germans in charge of rocket development not to bring in, even in an advisory capacity, the man on whose ideas were based all their own plans and projects. Professor Oberth's case is by no means unique in this respect; I could mention also those of Professor Sanger and Ing. Moritz Poehlmann. The reason for this peculiar behaviour was that the people concerned in the novel task of rocket development included a number who had cause to be afraid of the competition of a real expert in this field.

(The letter from our correspondent then goes on to deal with Oberth's practical researches in the development of a powder-fuelled AA rocket, which illustrates Professor Oberth's capacity for practical rocket engineering. The basis of this rocket was a device to vary the throat area of the nozzle during firing, so that constant combustion pressure was maintained. In this way, solid propellants could safely be used which otherwise would have had unstable burning characteristics giving dangerous pressure rise after ignition. It is claimed that Oberth also made significant contributions to the technique

of actually manufacturing solid propellant charges. He then continues. . . .)

I have heard quite a few criticisms of Professor Oberth, and have always tried to judge them on their merits. The greater number have come from those who feared Oberth as a possible competitor and who had an axe to grind in adversely criticising him.

In learning from the papers of Professor Oberth's election to the first Honorary Fellowship of the B.I.S., which has pleased me very much indeed, I feel that this is now a suitable opportunity for openly discussing these things.

OTTO HESTER.

RECENT AND FORTHCOMING MEETINGS

September 23, 1949 (Friday). "Interplanetary Travel," by A. C. Clarke, at St. John and St. Martin's College, Chelsea, S.W.3, at 8.15 p.m.

October 1, 1949 (Saturday). The Society's opening feature for the 1949-50 session will be the Conversazione at St. Martin's School of Art, 107, Charing Cross Road, W.C.2, commencing at **3 p.m.**

October 21, 1949 (Friday). "Atomic Energy and Interplanetary Travel," by A. C. Clarke to the World Forum for Science, Philosophy and the Arts, at the Waldorf Hotel, W.C.2, at 8 p.m.

October 22, 1949 (Saturday). "Possibilities of Interplanetary Travel," by L. Sykes and E. Burgess to the N.W. Branch of the Society at Adult Education Institute, 49, Lower Mosley Street, Manchester, 2, at 6.30 p.m.

October 26, 1949 (Wednesday). A lecture on "Interplanetary Flight," by A. V. Cleaver to the Gloucester and Cheltenham Branch of the R.Ae.S.

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